生物策略表

類別	Biological Strategy（生物策略）
生物策略 STRATEGY	地下網絡分配資源（Underground Network Distributes Resources）
生物系統 LIVING SYSTEM	菌根真菌（*Mycorrhizal fungi*）
功能類別 FUNCTIONS	在生態系統中合作（Cooperate Within an Ecosystem）
作用機制標題	共生菌網絡，以運輸養分和水，維護森林多樣性 (Mycorrhizal network sustains diversity in a forest by transporting nutrients and water.)
生物系統/作用機制示意圖 (確認版權、註明出處；畫質)	 https://sl.bing.net/gsJNIfYv8Qm

作用機制摘要說明 (SUMMARY OF FUNCTIONING MECHANISMS)

Introduction:

In a Douglas-fir and pine forest in North America there are trees of all ages, ranging from tiny seedlings to giants that are hundreds of years old. Hidden in the soil is a vast network made up of millions of miles of thin threads called mycelium. Most of the mycelium spread throughout this forest are mycorrhizal fungi. These are fungi that live in a mutualistic partnership with trees and other plants.

The mycelium acts like an internet network but instead of moving electronic information around, they transport water and chemicals to keep the trees alive and communicating with each other. This network has been called the “Wood Wide Web”.

The Strategy

On the internet, nodes are individual computers and the network moves information among them. Hubs are places that connect lots of nodes together and have a lot of information traveling through them, such as Google. The nodes of the Wood Wide Web are all the individual trees in the forest. The oldest trees, which are often also the tallest and largest, are the ‘hubs’ because they have the most connections running through them.

Mycelia form the connections between all the nodes in the Wood Wide Web. The mycelia wrap around the fine roots of the hub tree and other vegetation, snuggling so close that water, nutrients, and other chemicals can move between the cells of the roots and fungi. A hub tree has more access to sunlight than smaller trees because of its size. Sometimes that results in it producing too much sugar through photosynthesis. When this happens, it sends the sugar out through the mycelium

network to be used by its own seedlings and even other species of trees. The fungi take some of the sugar as it passes between trees and use it for themselves.

Water is also shared among the fungi and plants in the network. The water and nutrients increase seedling growth and help other trees survive. At another time, if the hub tree is stressed and needs water or nutrients, the mycelium and other trees can send them back to the hub tree.

But this isn't just about one hub tree. It's about a hub tree connected to a seedling connected to a sapling, connected to another hub tree, and so on. Researchers at a study site in Canada discovered that one tree was connected to 47 others through this network. Sixty percent of the tree species in the world are associated with these mycorrhizal fungi. Most trees form symbioses with a wide variety of fungal species (there are more than 5000 of them) and each species of fungus can have relationships with a wide variety of trees.

Besides sharing nutrients and water, the network also sends warnings. If a tree is attacked by a bark beetle, it sends out a chemical signal, called a defense signal. The mycelium passes this signal along to other nearby trees. When they get the signal, they reinforce their chemical defenses, which makes it easier for them to fight off an attack when it comes.

The Potential

The Wood Wide Web can show us the value of sharing resources, efficient ways to move them, and the importance of forming close partnerships. We also can learn how to manage our forests better to maintain this underground network that provides mutual support to all partners.

導言：

在北美洲的花旗松（Douglas-fir）與充斥松樹的森林中，擁有廣泛年齡的植披，它們的範圍從初冒細芽的種子到數以百年的神木。藏覓在土壤內的是一個由數百萬英里細線構成，即是所謂的菌絲體組成的廣泛網絡。遍布這座森林的菌絲體，幾乎是菌根真菌。這些真菌和不同種的樹木及其他植物形成共生夥伴關係。

菌絲體（mycelium）運作如同網際網絡，但並非傳遞電子訊息，而是運輸水和化學物質來維持樹木生機和促進樹木彼此間的溝通。這個網絡被稱為「木聯網」(“Wood Wide Web”)。

策略：

在網路上，節點是個別的電腦，網絡則是在它們之間傳遞訊息。樞紐是連結大量節點和擁有很多訊息傳遞的地方，例如 Google。木聯網的節點都是森林中的每棵樹。最古老的樹木通常也是最高大且最粗壯的，它們是樞紐，因為有最多的連結通過它們。

菌絲體形成了木聯網中所有節點之間的連結。菌絲體包裹住樞紐樹細根和其他植物的根部，緊密貼合，使水分、營養和其他化學物質能在根部細胞與真菌之間傳遞。一棵樞紐樹因為體型比較大，相比較小的樹木，樞紐樹因體型較大而能接受更多陽光。有時這會導致光合作用產生過多的糖分。當這個情形發生時，它會透過菌絲體網絡將多餘的糖分傳送給自己的幼苗，甚至支援其他樹種。真菌在糖分於樹木之間流動時，會吸取部分糖分供自己使用。

網絡中的真菌和植物也會分享水分。水分和營養促進幼苗的生長並幫助其他樹木存活。在某些情況下，如果樞紐樹受到壓力並需要水分或營養，真菌和其他樹木會通過菌絲網絡將水分和營養回傳給樞紐樹。

但這並非僅限於樞紐樹。樞紐樹連接著幼苗，再連接著小樹苗，然後再連接到其他樞紐樹，形成一個互相連接的網絡。在加拿大的一個研究場域，研究人員發現，一棵樹透過這個網絡與四十七棵其他樹木相連。全球有六成的樹種和這些菌絲真菌建立共生關係。大多數的樹與廣泛的真菌種共生（超過五千種的真菌）和每種真菌都可以與廣泛的樹種形成共生關係。

除了分享營養和水分，這個網絡還可以傳送警告信號。如果一棵樹遭到樹皮甲蟲的攻擊，它會向外釋放化學信號，稱為防衛信號。菌絲體傳遞這個信號給周圍的其他樹木。當它們接收到信號後，會強化自己的化學防禦，能使它們在面對襲擊時更有效地抵擋。

潛力：

「木聯網」對我們展示了分享資源的價值、資源效率化流動的方式，以及建立緊密合作夥伴關係的重要性。我們也可以學到如何更好地管理森林，以維護這個為所有夥伴提供相互支持的地下網絡。

文獻引用 (REFERENCES)

"Adaptive behaviour of plants, including rapid changes in physiology, gene regulation and defence response, can be altered when linked to neighbouring plants by a mycorrhizal network (MN). Mechanisms underlying the behavioural changes include mycorrhizal fungal colonization by the MN or interplant communication via transfer of nutrients, defence signals or allelochemicals…We have found that the behavioural changes in ectomycorrhizal plants depend on environmental cues, the identity of the plant neighbour and the characteristics of the MN. The hierarchical integration of this phenomenon with other biological networks at broader scales in forest ecosystems, and the consequences we have observed when it is interrupted, indicate that underground 'tree talk' is a foundational process in the complex adaptive nature of forest ecosystems." (Gorzelak et al. 2015:1)

「植物的適應性行為，包括生理、基因調控及防禦反應的迅速變化，會在與鄰近植物透過菌根網絡（MN）相連時發生改變。導致這些行為改變的機制包括透過菌根網絡的菌根真菌殖入，或通過營養、防禦信號或化感物質的傳遞進行的植物間溝通……我們發現，外生菌根植物的行為改變取決於環境線索、植物鄰居的特性，以及菌根網絡的特徵。這一現象在森林生態系統中與其他生物網絡的更廣泛尺度層級整合，及其中斷時觀察到的後果，表明地下「樹木對話」是森林生態系統複雜適應性本質中的基礎性過程。」(Gorzelak 等人，2015：1)

參考文獻清單與連結 (REFERENCE LIST) **Harvard 或 APA 格式**

Inter-plant communication through mycorrhizal networks mediates complex adaptive behaviour in plant communities

AoB Plants | May 15, 2015 | Gorzelak MA, Asay AK, Pickles BJ, Simard SW

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4497361/

Architecture of the wood-wide web: Rhizopogon spp. genets link multiple Douglas-fir cohorts
New Phytologist | October 29, 2009 | Beiler KJ, Durall DM, Simard SW, Maxwell SA, Kretzer AM
https://doi.org/10.1111/j.1469-8137.2009.03069.x

Mycorrhizal networks facilitate tree communication, learning, and memory
Memory and Learning in Plants | April 24, 2018 | Simard SW
https://link.springer.com/chapter/10.1007/978-3-319-75596-0_10

The Wood Wide Web
The Atlantic | April 14, 2016 | Yong E
https://www.theatlantic.com/science/archive/2016/04/the-wood-wide-web/478224/

延伸閱讀: Harvard 或 APA 格式（取自 AskNature 原文；若為翻譯者補充，請註明）

無

生物系統延伸資訊連結 (LEARN MORE ABOUT THE LIVING SYSTEM/S)

無

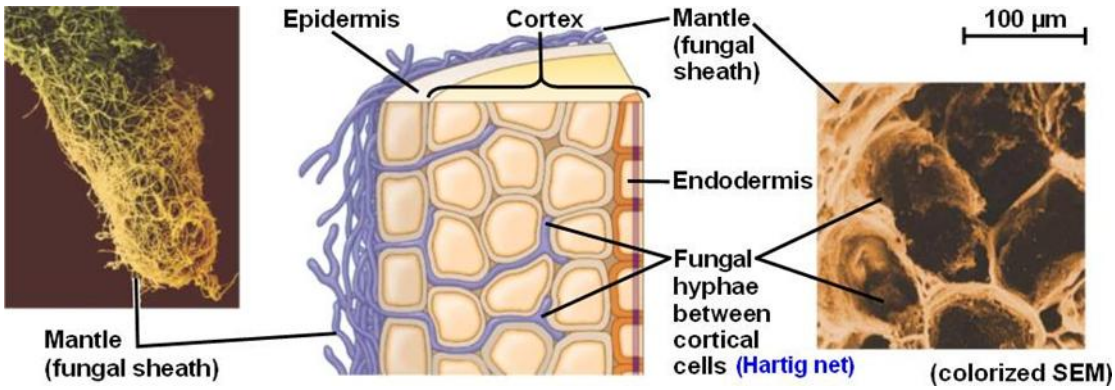
撰寫/翻譯/編修者與日期

徐淑婷翻譯 (2025/03/26)；許秋容 (2025/04/07)

AskNature 原文連結

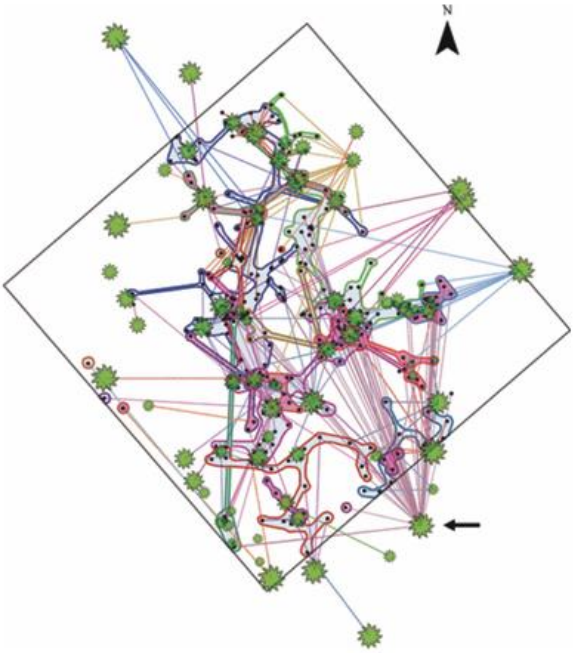
https://asknature.org/strategy/fungal-network-distributes-resources/

更多補充的圖片 (1. 確認版權、註明出處 2. 品質: 盡量 72dpi 或 300K)



出處： https://sl.bing.net/32VvVrRpQ

解析度：600x206



出處：Beiler, et. al. https://ask-nature.sfo3.digitaloceanspaces.com/wp-content/uploads/2020/11/31104326/AN-Mycorrhizal-Fungi-Network.pdf
解析度：1,200X1,358